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FACTORS WHICH MAY MODIFY THE COLD PRESSOR RESPONSE

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled FACTORS WHICH MAY MODIFY THE COLD PRESSOR RESPONSE ....

submitted by MARK LUND ....

in partial fulfilment of the requirements for the degree of Master of Science in Physical Education.

ABSTRACT

The Cold Pressor Response (CPR) to the Cold Hand Test (CHT) was evaluated in thirty-five Caucasian volunteers, twenty-two men and thirteen women. Physical fitness (predicted aerobic capacity (ml O_2/kg/min), per cent body fat, hand volume, age and sex were evaluated for each subject. Physical fitness was predicted from the Astrand six-minute bicycle ergometer test, per cent body fat from underwater weighings, and hand volume was measured by a water displacement method. Correlation coefficients were computed between each variable and the CPR. No significant correlations were found between the variables and the CPR except for age. Increasing age was found to relate ($r=.357$, $P<.05$) with a larger CPR. The female subjects showed a strong tendency ($r=.529$, $P<.1$) for larger hands to maintain warmer fingers during the CHT. From the results of this study and a review of related literature, the author suggests that future studies of factors modifying the CPR need to measure the subcutaneous fat of the extremity exposed.

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INTRODUCTION

The capacity to tolerate exposure to cold appears highly variable between individual human beings. This capacity affects many aspects of a person's ability to function in a cold environment, or his susceptibility to being incapacitated by cold or even to suffer cold injury. An understanding of the mechanisms of the responses to cold exposure, and the factors which may modify responses to cold exposure, and consequently an individual's capacity to tolerate cold exposure, is an important attribute for those involved in the leadership of outdoor activities.

With repeated or prolonged exposure to cold, man, like other homeotherms, becomes acclimatized so that he is better able to cope with a low temperature environment. In other mammals acclimatization is associated with a number of readily demonstrable changes in basic physiological mechanisms by which they maintain constant body temperatures. Scholander et al. (1950[b]) observed that all homeotherms, including man, must make adjustments to insulation or heat production in order to maintain thermal homeostasis.

Several reflex mechanisms which contribute to the regulation of body temperature are well recognized. For example, with an exposure to cold, heat production may be increased through shivering, or heat loss may be reduced by increasing thermal insulation. The latter may include peripheral vasoconstriction, piloerction, and postural changes.

With acclimatization to cold several changes are seen in these processes. Small mammals in particular develop an augmented means of

heat production, not involving shivering (non-shivering thermogenesis) (Cottle, 1958). Body insulation in many mammals is improved through the growth of longer and thicker fur or hair.

The possibility of cold injury to the extremities is an additional problem posed by cold exposure. However, animals acclimatized to cold have been found to be less susceptible to cold injury of the extremities than those animals which are not acclimatized. Blair (1952) has reported such findings and concluded that the reduced susceptibility reflected an apparent increase in blood flow to the extremities as a result of the prolonged cold exposure. Presumably, if such an adjustment of blood flow occurred in man as a result of cold acclimatization, it would mean that hands and feet would be maintained at higher temperatures in the cold, and consequently suffer less discomfort, improved dexterity, and the extremities would be less susceptible to cold injury.

That human subjects maintain warmer hands in the cold after acclimatization was reported by Carlson et al. (1953). Carlson and co-workers studied U.S. Army soldiers before and after a series of winter maneuvers in Alaska. They concluded that the increase in heat flow to the extremities was at the expense of heat loss from other parts of the body.

The winter maneuvers that Carlson's (1953) subjects were drawn from involved a good deal of physical activity. Adams and Heberling (1958) suggested that the results of Carlson et al. (1953) may also be attributed to the improved physical fitness of the subjects that would result from the physical activity required by the maneuvers. They applied tests similar to those used by Carlson et al. (1953) to subjects

before and after taking part in a physical fitness program. They found changes very similar to those reported by Carson et al. (1953) and concluded that such changes as reported by Carlson and many others were a reflection of changes in physical fitness. Other workers, including Andersen et al. (1966), LeBlanc et al. (1978), Heberling and Adams (1961), and Keatinge (1960), have also provided evidence that improved physical fitness produces physiological response changes to cold very similar to those attributed to cold acclimatization, and these adjustments enhance man's tolerance to cold.

A number of other factors besides physical fitness have been reported to modify man's responses to improve his capacity to cold exposure. Keatinge (1960) observed that subcutaneous fat has a direct inverse relationship with the fall of rectal temperature during cold water immersion. Kollias et al. (1972) has made similar observations regarding the insulative value of subcutaneous fat during whole body exposure of men to cold air. LeBlanc et al. (1978) has reported that age reduces the cardio-accelerator response of hand exposure to cold water and that the heart rate and blood pressure of women remains depressed following a cold exposure of the face or hand. Goldby et al. (1938), Meehan (1955), and Wyndham and Morrison (1958) have all found that primitive ethnic groups are more tolerant of various cold exposures than Caucasians. Others have reported that fishermen maintain warmer hands, demonstrate smaller cold pressor response, and suffer less pain on exposure of their hands to cold water than control groups (LeBlanc et al., 1960; Nelms and Soper, 1962; Krog et al., 1960). Davis and Johnston (1961) have reported that subjects exposed monthly to an whole body cold exposure shiver less each month from October to February and

more from February to September.

Not all authors have found that improved physical fitness contributes to man's capacity to tolerate cold. Kollias et al. (1972) found improved levels of physical fitness after an extended training regime, but, contrary to the results of Adams and Heberling (1958), heat production fell during the two-hour exposure to cold air. Eagan (1963) found no relationship between physical fitness and the temperature of a finger immersed in ice water. He has suggested that the elevated heat production reported by Adams and Heberling (1958) may have been the result of increased protein intake during the fitness training regime, resulting in an elevated basal metabolic rate (BMR); or that strenuous exertion may elevate the BMR for longer than twenty-four hours.

Statement of the Problem

In view of the contradictory evidence, the purpose of this study was to investigate the factors, including physical fitness, which may modify man's vascular responses to a cold exposure. The Cold Hand Test (CHT) as developed by LeBlanc et al. (1960, 1975, 1978) was chosen as the cold exposure. The hands of Canadians are often subject to cold exposure, and occasionally suffer cold injury; consequently, information regarding factors which may prevent cold injury or improve manipulatory efficiency in the cold would be beneficial. Also, the hands are easily manipulated for testing purposes. Variables measured during the CHT include arterial blood pressure (the Cold Pressor Response - CPR), heart rate, and finger temperature. LeBlanc et al. (1960, 1975, 1978) has reported that Eskimos, fishermen, and the physically fit all exhibit a

reduced CPR to the CHT when compared to control groups.

This study has made an attempt to answer the following questions:

1. Will subjects with a larger per cent body fat respond (CPR) less during the CHT than less fat individuals?
2. Is a person of greater physical fitness (predicted aerobic capacity) likely to respond (CPR) less during the CHT than a less fit subject?
3. Will an older individual respond (CPR) less during the CHT than a younger person?
4. Does hand size affect how an individual responds (CPR) during the CHT?
5. Do women respond (CPR) less or more during the CHT than men?

Definition of Terms

Adaptation: a generic term which includes acclimation, acclimatization, and habituation. It includes all changes in the physiological responses and morphologies of organisms which result from changes in environment.

i. Acclimation: the changes or adjustments made over a period of days to weeks in response to a single experimentally controlled environmental change.

ii. Acclimatization: the changes or adjustments made over a period of days to weeks in response to a complex of environmental changes.

iii. Habituation: changes and adjustments in physiological response and in sensation resulting from a diminuation in the responsiveness of the central nervous system to certain stimuli (from Eagan, 1963).

Bradycardia: a slowing of the heart rate.

Cold Induced Vasodilitation (CIVD): the spontaneous rewarming of the skin of the extremities and other areas of the body during continuous exposure to cold.

Cold Pressor Response (CPR): the increase in arterial blood pressure associated with exposure of extremities to cold water. The Cold Pressor Test and Response was first devised by Pickering and Kissin (1936) as a means to study hypertension.

Metabolic Rate: the magnitude of heat production as assessed by the measurement of oxygen uptake.

i. Metabolic Response: a change in the metabolic rate.

ii. Basal Metabolic Rate: the metabolic rate determined

under the following conditions:

a. no food for the previous twelve hours.

b. after a night of restful sleep.

c. no strenuous exercise before the determination, and

d. carried out at an ambient temperature between 18°C and 20°C (from Guyton, 1971).

Physical Fitness: the estimated ability of the body to utilize oxygen determined from heart rates during a bout of intense cycling on a bicycle ergometer (as described by Astrand and Rodahl, 1970).

REVIEW OF THE RELATED LITERATURE

Introduction

Man's responses, tolerance, and adaptations to cold exposures have been extensively studied over the past fifty years. This review has been limited to the following:

1. the vascular responses of the extremities during cold exposure, including cold-induced vasodilatation (CIVD).
2. heart rate responses to cold exposure, including bradycardia or the "diving reflex."
3. what may be the potential modifiers of responses to cold exposure, including age, sex, body fatness, physical fitness, occupation, ethnic origin, season, and hand size.
4. the interrelationship (or the ability of one cold exposure test to predict the results of another cold exposure test) of the various cold exposure tests that the many different authors have used over the years.

Vascular Responses of the Extremities

Whether one's hand, finger, or foot becomes cold as a result of exposure to a cold environment or as a result of the Cold Hand Test (CHT), the body responds to the cooling. Lefevre (1901), as cited by

Keatinge (1969), determined from measurements of temperature gradients and heat flow within the skin, that the apparent thermal conductivity of human skin falls with exposure to cold. This apparent reduction in tissue thermal conductance is well recognized to be largely the result of reduced blood flow. Both Brown and Page (1952) and Elkington (1968), through the technique of a venous occlusion plethysmograph, have observed reduced blood flow as a result of cold exposure. Edwards and Burton (1960) combined a venous occlusion plethysmograph and a gradient calorimeter to study heat output and blood flow in a cold exposed finger. They demonstrated that heat loss and blood flow are correlated only during steady state conditions, and that skin temperature is a good indicator of heat loss.

It is well-established that the primary means of control of blood flow to the extremities is the sympathetic nervous division of the autonomic nervous system. Temperature, though, may have a direct effect, causing arteries to constrict. Many of the studies providing evidence for the sympathetic control of blood flow in the extremities have been reviewed by Greenfield (1963). Of interest is his review of the early evidence provided by Claude Bernard, 1851 to 1858. Bernard showed that division of the cervical sympathetic chain in the rabbit caused the ear on the same side to flush and become warm. Stimulation of the trunk had a reverse effect. These observations indicated that the sympathetic nerves contain vasoconstrictor fibers. Further support for these conclusions has come from Grant (1930) and Keatinge (1966). Grant (1930) applied adrenalin, which at that time was recognized as a probable transmitter substance in the sympathetic nervous system, to arteries in rabbit ears, and observed an intense vasoconstriction. Keatinge (1966)

stimulated the cervical sympathetic nerve in anesthetized sheep and observed a 30 to 39 per cent reduction in the carotid artery.

The evidence that cold temperatures may have a direct effect in reducing blood flow includes the work by Lewis and Landis (1930) and Smith (1952). Lewis and Landis (1930) observed that after the sympathetic nervous supply had been cut, local cold would reduce the blood flow in the fingers. Further, Smith (1952), using isolated pig arteries, found that these arteries contracted with the application of cold.

Cold-Induced Vasodilatation

Cold-induced vasodilation (CIVD) was first reported by Lewis in 1930. When a finger is immersed in water near 0°C, there is first a rapid fall in temperature associated with an intense vasoconstriction. Lewis (1930) observed the expected fall in temperature, but after a time period of 5 to 10 minutes there was a rise in the finger temperature which was attributed to a vasodilatation of the blood vessels of the finger and a direct result of the cold exposure. Lewis found that to consistently bring on this CIVD the water temperature must be less than 15°C, room temperature must be greater than 17°C, and an initial finger temperature of 25°C to 28°C was required. If the finger is immersed for an extended period of time, the finger temperature will fall after the initial vasodilatation, then later rise again. Each successive rise in temperature tends to be less than the previous. Lewis termed this a "hunting" phenomenon. Lewis found CIVD and the hunting phenomenon clearly in the fingers and toes, and to a lesser extent in the lobes of the ears, the nose, and the chin.

The CIVD response appears most pronounced in the fingers, toes, and ears; those areas of the body which are supplied with a large number of arteriovenous anastomases in the cutaneous circulation. This was demonstrated by Grant and Bland (1930). However, Fox and Wyatt (1961) tested 34 sites for CIVD for 30 minutes, and concluded that this phenomenon is found in all areas of the body likely to be exposed to severe local cooling in cold climates.

The controlling mechanism for the CIVD response is still not clear. Lewis (1930) suggested that CIVD was due to a sensory nerve axon reflex. Keatinge (1958, 1964), using both bullock and sheep arterial strips, has concluded that cooling arteries below 5°C causes a collapse of vasoconstrictor tone and a dilatation of the arteries. Keatinge (1964) has suggested that the mechanism for the loss of this vasoconstrictor tone may be one of the following: cold depresses energy metabolism in the cell and this inhibits the action of noradrenalin at the cell membrane; or cold depresses the depolarization contraction link in the cell.

Diving Bradycardia - the Diving Reflex

A further physiological response, related to blood flow, which may be altered by cold acclimatization, is the slowing of the heart rate when the face is exposed to cold water or to a cold breeze. This response may be related to the so-called diving reflex or diving bradycardia of sea mammals. The diving reflex in mammals involves the slowing of the heart rate at the onset of a dive; heart rate remains depressed until the dive's conclusion. This response can be elicited by immersing an animal's head in cold water, or in man by the immersion of

one's face in cold water, or the blowing of cold air onto the face (LeBlanc et al., 1976). Andersen (1963) has demonstrated that the diving reflex is the result of vagal nerve action. LeBlanc et al. (1975, 1978) has assumed that the bradycardia response to the Cold Face Test (CFT) reflects parasympathetic activity.

Factors Modifying Responses to Cold Exposure

The responses described above are highly variable between subjects. A part of the variation in responses between subjects may be attributed to individual differences; but a number of factors have been reported to alter or segregate how individuals may respond to a cold exposure. Many of the studies and findings relating various factors with differing or altered cold exposure responses are reviewed below.

Sex

It is well recognized that women tend to be smaller than men, and tend to have thicker deposits of subcutaneous fat. These two factors alone have prompted physiologists to postulate that women would respond differently than men to cold exposure. Hardy and Dubois (1940) reported that women maintain colder skin temperatures during a cold exposure. As indicated in Table 2-1, Wyndham et al. (1964) has reported similar results, but found that the lower metabolic response of the women was similar to the men's metabolic response when related to total surface area of the body. Wyndham attributes the lower skin temperatures to the thicker subcutaneous fat of the women, and this conclusion is supported by the work of Hong (1963) and Lee et al. (1965).

The above studies all involved whole body exposures to cold air.

LeBlanc et al. (1978), Itoh (1974), and Krog et al. (1969) have all reported on sex differences in the response to extremity cold exposures. LeBlanc et al. (1978) found contradictory and minimal differences between the sexes in the CPR and heart rate responses to the CFT and CHT. Itoh (1974) and Krog et al. (1969) both studied the effects of sex to extremity cold exposure responses within ethnic groups: Itoh studied Japanese students and Krog the Skolts of Finland. Both authors report no sex-related differences in response to cold exposure.

TABLE 2-1

Sex as a Modifier of Responses to Cold Exposure

Author	Study Groups	Test	Responses Measured	Results
Wyndham, C.H. et al., 1964	1. 9 women 2. 44 men	1. exposure to 27°C and 5°C air for 90 min.	1. O_2 consumption (MR) 2. T skin	1. Metabolic rates of females lower than males at both 27° and 5°C. But similar when expressed O_2 per square meter of body surface. 2. T skin 2°C lower in females at 5°C.
LeBlanc, J. et al., 1978	1. 9 men 2. 8 women	1. Cold Hand Test (CHT) 2. Cold Face Test (CFT)	1. Arterial Blood Pressure 2. Heart Rate 3. T skin (hand or face)	1. CHT - Women's B.P. change less at end of test and during 2-min. recovery. Women's H.R. increase greater during CHT and their bradycardia greater during recovery. CFT - Women's bradycardia greater during recovery from CFT.
Itoh, S., 1974	1. 16 Sapporo male students 2. 35 Asahikawa female students	1. Finger Immersion in 0°C water for 20 min.	1. Time to CIVD 2. Ts at onset of CIVD 3. ΔTs during immersion	1. No differences in responses between these two groups.
Krog, J. et al., 1969	1. 30 female "Skolts" 2. 26 male "Skolts"	1. Hand immersion in 0°C water for 15 min.	1. Time to CIVD 2. Magnitude of CIVD 3. C.P.R.	1. No difference between the sexes was found.

Age

From Table 2-2 it appears that persons over approximately sixty years of age may have diminished responses to cold exposure. Collins et al. (1980) suggests that the autonomic neural pathways may become impaired with age. This may account for Krog's (1969) findings, within a younger age range of subjects, of no effect of age. Little (1968) attributes the age effect between the Peruvian natives of 14 and 31 years to an acclimatization process.

TABLE 2-2

Age as a Modifier of Response to Cold Exposure

Author	Study Group	Test	Responses Measured	Results
Horvath, S.M. et al., 1956	1. 8 subjects age 52 to 76 2. 7 controls age 22 to 27	1. Whole body exposure to cold air 10°C for 10 to 49 min.	1. O_2 consumption	1. Older group no metabolic response. 2. Younger group large metabolic response.
Collins, K.J. et al., 1980	1. 43 subjects mean age 78±4 2. 10 controls mean age 24±4	1. Fox Bed Test (see Appendix 2-A)	1. T body 2. Shivering and sweating 3. Hand blood flow (Volume Plethysmograph)	1. Aged have non-constrictor pattern of response to cold, and postural hypotension which may indicate increased susceptibility to hypothermia.
LeBlanc, J. et al., 1978	1. 9 subjects 20-47 yrs. 2. 8 subjects 53-60 yrs.	1. Cold Hand Test 2. Cold Face Test	1. Blood Pressure 2. Heart Rate 3. Skin Temperature Face or Hand	1. Older subjects showed lower H.R. response to CHT and greater bradycardia to CFT.
Krog, J. et al., 1969	1. 30 female "Skolts" age 11-75 yrs. 2. 26 male "Skolts" age 12-63 yrs.	1. Hand Immersion in 0°C water for 15 min.	1. Time to CIVD 2. Magnitude of CIVD 3. CPR	1. No correlation to age existed in the three responses.
Little, M.A., 1968	1. 29 Peruvian Indians mean age 14.1 yrs. 2. 28 U.S. whites mean age 12.9 yrs. 3. 30 Peruvian Indians mean age 31.6 yrs. 4. 26 U.S. whites mean age 27 yrs.	1. Foot Exposure to 0°C air for 60 min.	1. T_S of a foot at 3 sites	1. Older Indians maintained warmer foot skin Ts than young Indians ($P<.05$). 2. No difference in foot skin Ts between young and old U.S. whites.

Body Fat

The subcutaneous layer of fat is widely accepted as being of some insulative value to all homeotherms, including man. Both studies reviewed in Table 2-3 conclude that, in whole body exposure to cold air, the thickness of the subcutaneous layer of fat correlates with man's metabolic response to cold. Keatinge (1969), in reviewing studies related to cold water immersion, concluded that subcutaneous fat was the most important factor determining fall in body temperature.

Body fatness and extremity cooling has been the subject of far fewer studies than the question of whole body exposures. Little (1968) studied the responses of both Quecha Indians of Peru, and a control group of U.S. whites, to cold air exposure of one foot. The U.S. adult whites (see Table 2-6) demonstrated a correlation of $r=.554$ ($P<.05$) between the sum of eight skinfolds and average toe temperatures. The Peruvian natives, though, showed no consistent relationship between skinfold measurements and average foot temperature. Little attributes this largely to the small variation in skinfold measurements between the natives, both young and old.

TABLE 2-3

Body Fat as a Modifier of Responses to Cold Exposure

Author	Study Group	Test	Responses Measured	Results
Buskirk, E.R. et al., 1963	1. 8 healthy young men age 19 to 35 2. 4 older men age 38 to 42 3. 3 obese subjects (2 female, 1 male) age 20 to 34	1. Whole Body exposure to 10°C air for 2-4 hrs.	1. O_2 consumption (MR)	1. Metabolic response greater in lean subjects ($P < .05$).
Kollias, J. et al., 1972	1. 10 subjects (6 lean, 4 obese)	1. Whole Body exposure to 10°C air for 2 hrs.	1. O_2 consumption (MR) 2. T skin 3. T skin - subcutaneous 4. T body	1. Metabolic response greater for lean group from 60-120 mins. of exposure ($P < .05$). 2. Obese group maintained larger temperature gradient than lean subjects ($P < .05$).

Physical Fitness

A number of authors have reported that human subjects, after an intensive physical fitness training program, maintain warmer extremities in a whole body cold exposure. From Table 2-4 it may be noted that Adams and Heberling (1958), Andersen et al. (1966), Heberling and Adams (1961), and Keatinge (1960) have all provided results supporting this finding. LeBlanc et al. (1978) observed a correlation ($r=-.57$, $P<.01$) between levels of physical fitness (VO_2 max.) and the CPR, to the CHT. Contrary results, both to the whole body cold exposure studies (Kollias et al., 1972) and extremity cold exposure (Eagan, 1963) studies are reviewed in Table 2-4.

TABLE 2-4

Physical Fitness as a Modifier of Cold Exposure Responses

Author	No. Subjects	Training Regime	Cold Test	Responses Measured	Results
Adams, T., Heberling, E.J., 1958	1. 5	1. 3 wks. running, calisthenics, gym sports	1. 1 hr. Whole Body Exposure to 10°C air	1. T_R 2. T_{Sk} 3. O_2 Consumption (MR)	1. Improved fitness ($P<.01$). 2. Increased MR after training. 3. Increased TSk and decreased T_R after training.
Andersen, K.L., et al., 1966	1. 19	1. 6 wks. systematic physical training and 4 hrs. manual labor per day, outside	1. Scholander Sleeping Bag Test 2. CHT	1. Amount of sleep (EEG) 2. Shivering 3. O_2 Consumption (MR) 4. Thermal Response 5. Finger Blood Flow 6. CPR	1. Improved ability to sleep. 2. Increased shivering. 3. Increased MR. 4. 10-15% increase in tissue conductance. 5. Increased finger blood flow. 6. Reduced CPR.
Heberling, E.J., Adams, T., 1961	1. 5	1. 4 wks. running, calisthenics, gym sports 2. 6 wks. winter bivouac	1. 1 hr. Whole Body Exposure to 10°C air	1. T_R 2. T_{Sk} 3. O_2 Consumption (MR)	1. After exercise phase subjects maintained higher mean skin, and hand and foot Ts during cold exposure. 2. No difference between exercise and bivouac phases. 3. No change in MR.

TABLE 2-4 (cont'd)

Physical Fitness as a Modifier of Cold Exposure Responses

Author	No. Subjects	Training Regime	Cold Test	Responses Measured	Results
Keatinge, W.R., 1961	1. 14	1. 7 1/2 hrs./ day, 19 of 21 days of stepping exercises and playing sports	1. 6 1/2 hrs. Cold Air Exposure at 6°C	1. O_2 Consumption (MR) 2. T_R 3. T_{Sk} 4. Electromy-graphs of right forearm	1. Physical training reduced men's immediate metabolic response to cold. 2. Physical training increased forearm skin Ts during the cold.
Kollias, J., et al. 1972	1. 10	1. 9 wks. 51 1 hr. sessions of progressive calisthenics and running	1. Whole Body Exposure to 10°C air for 2 hrs.	1. O_2 Consumption (MR) 2. T_R and T_{ES} 3. T_{Sk} 4. 2 subcutaneous T (forearm and upper arm)	1. No change in MR during cold exposure. 2. Decrease in T_{Sk} and T_{Body} after physical training to cold exposure.
LeBlanc, J., et al. 1978	1. 12 males with VO_2 max. > 50 ml/kg/min. 2. 15 males with VO_2 max. > 50 ml/kg/min.		1. CHT a. CFT	1. Arterial Blood Pressure (CPR) 2. Heart Rate 3. T Finger and Face	1. r=.59 between VO_2 max. and increase in BP sys. in CHT ($P<.01$). 2. r=.42 between fall in cheek skin T and low VO_2 max. ($P<.05$).
Eagan, C.J., 1963	1. 20 controls 2. 5 mountain-eers 3. 4 Eskimos	1. Fitness scores - Mountaineers, Eskimo, controls	1. Finger Immersion in 0°C water for 10 min. a. Finger Exposure to wind chill of 850 Kcal/M^2/hr. at -22 C	1. T Finger	1. No difference between mountaineers and controls in finger T maintenance during both cold exposures.

Occupation

A number of occupations in our western society require that individuals come into regular contact with cold and wet conditions. It has been hypothesized that fishermen and others may become acclimatized to working with their hands cold and wet. LeBlanc (1960), Krog (1960), and Helms and Soper (1962) all found evidence that fishermen and fish filleters of the North Atlantic have acclimatized to their working conditions. Specifically, these fishermen either maintain warmer extremities or vasodilate sooner than controls during cold water immersions of their hands; and the fishermen show less CPR and suffer less discomfort. Hellstrom and Andersen (1960), though, observed no difference in heat loss (cal./100 ml. of hand) between the hands of Norwegian fishermen and Oslo controls.

TABLE 2-5

Occupation as a Modifier of Cold Exposure Responses

Author	Study Group	Test	Responses Measured	Results
Krog, J., et al., 1960	1. 11 Northern Norwegian fishermen 2. 12 Norwegian controls	1. Hand Volume plethysmograph 2. Hand Immersion - calorimetry in 0-1°C water for 30 min.	1. Volume of hand blood flow 2. Heat loss in cal/100ml of hand/min. for last 20 min. 3. Time to CIVD	1. Resting blood flow at 40°C, 20°C, 10°C and 0°C similar for both fishermen and controls. 2. Heat loss similar between fishermen and controls. 3. Fishermen's initial CIVD sooner than controls' ($P<.05$). 4. It was observed that the fishermen experienced less discomfort.
LeBlanc, J., et al. 1960	1. 14 Gaspé fishermen 2. 14 Gaspé laborers, lumberjacks, farmers, and truck drivers	1. CHT 10 min. in 2.5°C water 2. Mackworth Finger Numbness 3. Hand Calorimetry in 5°C water for 30 min. 4. Skin biopsies	1. CPR 2. Finger temperature 3. Gap size on a "V" shaped instrument (Mackworth Test) 4. Heat loss 5. a. Thickness of epidermis b. Total no. cells c. No. mast cells	1. Control group mean CPR, both systolic and diastolic B.P., 10 mm. higher than fishermen ($P<.01$). 2. Fishermen maintained higher finger temperatures than controls ($P<.01$). 3. Insignificant results on Mackworth Test. 4. Heat flow greater from fishermen's hands ($P<.05$). 5. Thickness of epidermis and total number of cells similar. Fishermen had larger number of mast cells.
Hellström, B, Andersen, K.L., 1960	1. 9 Norwegian fishermen 2. 9 Oslo controls	1. Hand Calorimetry in warm and cold rooms	1. Cal/100ml. of hand/min.	1. No difference in total heat loss found between fishermen and controls.

TABLE 2-5 (cont'd)

Occupation as a Modifier of Cold Exposure Responses

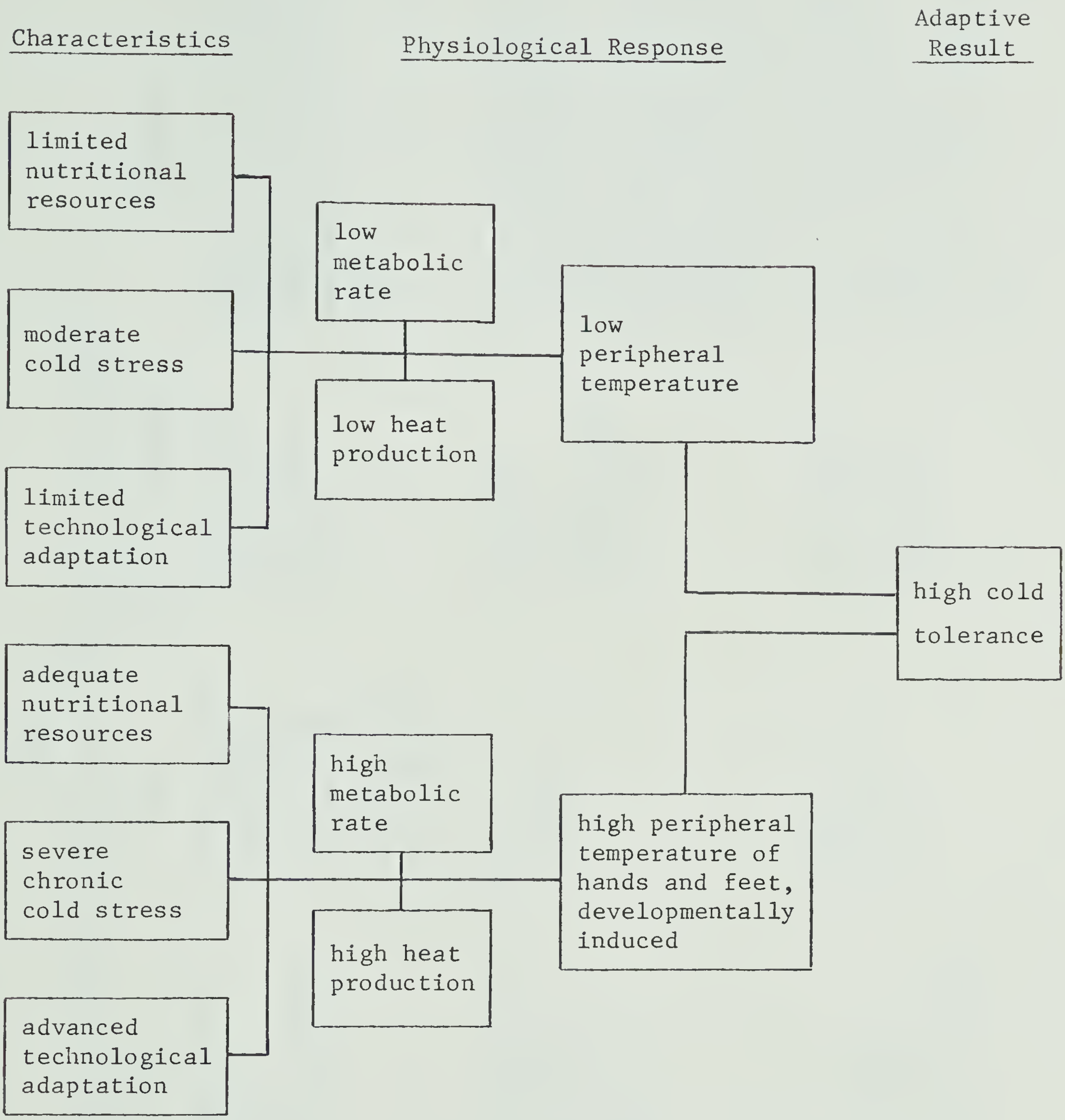
Author	Study Group	Test	Responses Measured	Results
Nelms, J., Soper, J., 1962	1. 11 British fish filleters 2. 9 controls	1. CHT in ice water	1. Time to CIVD 2. T skin before and after CIVD	1. CIVD occurred earlier in fish filleters. 2. Fish filleters maintained warmer skin temperatures both before and after CIVD.

Primitive Peoples

The process of acclimatization to cold has been described as requiring repeated or prolonged exposures to the cold; this has lead many authors to hypothesize that the primitive peoples from cold climates may exhibit modified responses to cold. The studies reviewed in Table 2-6 present an overwhelming majority of evidence that primitive peoples have acclimatized to their cold environments and these acclimatizations are beneficial to their functioning in their environment. Little's (1968) study observed that young Peruvian natives maintain warmer feet during cold air exposures than young U.S. whites, but not as warm as their elders. This suggests a genetic adaptation followed by acclimatization to the cold. That many primitive groups, when compared to controls from more technologically advanced societies or warmer climates, maintain warmer extremities, have a lower CPR, and feel less discomfort during extremity cold exposure, is supported by Elsner et al. (1960), LeBlanc et al. (1975), Itoh (1974), Little (1968), and others.

Similar results to the extremity exposure studies with primitive peoples have been found with whole body exposure tests. Frisancho (1979), in a recent review of ethnic adaptations to cold, has proposed the relationships outlined in Figure 2-1 between moderate and severe cold stress as suffered by various primitive peoples, their nutritional resources, and their technological developments.

FIGURE 2-1



Schematization of adaptive responses to cold of indigenous populations in environments of moderate and severe cold stress. Populations inhabiting environments of moderate and severe cold stress through specialized thermoregulatory responses, which are intimately related to degree of access to nutritional resources and technological adaptation, have attained high degree of cold tolerance. (From Frisancho, 1979)

TABLE 2-6

Ethnic Origins as a Modifier of Response to Cold Exposure

Author	Study Group	Test	Response Measured	Results
Elsner, R.W., et al., 1960	1. 9 Kutchin Indians 2. 8 Caucasian controls 3. 8 Kutchin Indians 4. 5 white controls	1. Hand Immersion in 5°C water in insulated bath for 30 min. at warm and cool room temperatures 2. Hand Immersion in ice water	1. Rate of heat transfer to water bath 2. T_f and T wrist	1. Indians maintained warmer hands. 2. Indians withstood hand immersion in ice water with quicker rewarming and less pain.
LeBlanc, J., et al., 1975	1. Eskimo men, women, girls, boys 2. White northern controls 3. White southern controls	1. CHT 2. Cold Face Test in water	1. Change in systolic blood pressure (CPR) 2. Change in heart rate	1. Eskimos demonstrated lower CPR to both CHT and CFT compared to southern controls. 2. White northern controls intermediate between Eskimos and white southern controls in CPR to CFT. 3. Bradycardia to CFT similar in whites and Eskimos.
Itoh, S., 1974	1. Ainu 2. Huren farmers 3. Monbetsu fish factory staff 4. Monbetsu fishermen 5. Asahikawa students	1. Finger Immersion in 0°C water for 20 min.	1. Time to CIVD 2. T_S at CIVD 3. ΔT_S during immersion	1. Ainu initiate CIVD sooner than, and maintain warmer fingers ($P<.001$) than student controls. 2. Ainu had similar responses as farmers and fish factory staff.

TABLE 2-6 (cont'd)

Ethnic Origins as a Modifier of Response to Cold Exposure

Author	Study Group	Test	Response Measured	Results
Brown, G.M., et al., 1954	1. 59 Eskimos 2. 85 Canadian medical students	1. Hand and Forearm Exposure to 5°C water for 2 hrs.	1. Forearm blood flow 2. Blood pressure 3. Perceived pain	1. Eskimos maintained greater blood flow than controls. 2. Cold exposure of 5°C water to the forearms brought about a larger B.P. response in Eskimos. 3. Eskimos reported less severe pain, and pain for less time than controls.
Iampietro, P.F., et al., 1959	1. 17 Caucasians 2. 16 Negroes	1. All fingers of right hand immersed in 0°C water for 45 min.	1. T middle finger 2. Time to vasodilatation	1. Negroes maintained lower finger temperature ($P<.01$). 2. Negroes took longer to first vasodilatation ($P<.05$). 3. Negroes vasodilatated from lower temperature ($P<.05$). 4. Negroes temperature peak during vasodilatation less ($P<.01$).
Krog, J., et al., 1969	1. 30 female Skolts age 11 to 75 2. 26 male Skolts age 12 to 63 3. 11 Norwegian controls	1. Hand Immersion in 0°C water for 15 min.	1. Time to vasodilatation 2. Magnitude of vasodilatation 3. CPR	1. Skolts vasodilatated sooner than Norwegian controls ($P<.05$). 2. CPR greater in Skolts than Norwegian controls.

TABLE 2-6 (cont'd)

Ethnic Origins as a Modifier of Response to Cold Exposure

Author	Study Group	Test	Response Measured	Results
Krog, J., et al., 1960	1. 13 Norwegian Lapps 2. 12 Norwegian controls	1. Hand Volume plethysmograph 2. Hand Immersion calorimetry in 0°C water for 30 min.	1. Volume of hand blood flow 2. Heat loss in cal/100ml. of hand/min. in 0°C water 3. Time to CIVD	1. No difference in mean blood flows at 40°C, 20°C, and 10°C. 2. Heat loss similar in Lapps and controls. 3. Lapps began CIVD sooner than controls ($P<.05$). 4. Lapps tended to experience less pain.
Little, M.A., 1968	1. 29 Peruvian Indians, mean age 14.1 yrs. 2. 28 U.S. whites, mean age 12.9 yrs. 3. 30 Peruvian Indians, mean age 31.6 yrs. 4. 26 U.S. whites, mean age 27 yrs.	1. Foot Exposure to 0°C air for 60 min.	1. Foot skin temperatures at 3 sites	1. Young Indians maintained warmer feet (T_{Sk}) than young whites ($P<.001$). 2. Older Indians maintained warmer feet (T_{Sk}) than older U.S. whites ($P<.001$).

Seasonal Variation

In our northern hemisphere the advancement of winter, with colder temperatures and cold winds, certainly provides the opportunity for repeated or prolonged exposure to cold. Davis (1961) confirms a seasonal change to whole body cold exposures - a diminishing metabolic response from October to February. LeBlanc et al. (1975) supports these findings, but Itoh (1974) found no seasonal variation in finger immersion studies.

TABLE 2-7

Seasonal Variations in Responses to Cold Exposure

Author	Study Group	Test	Responses Measured	Results
Itoh, S., 1974	1. 13 Huren farmers 2. 35 female Asahikawa students 3. 14 female Asahikawa nurses	1. Finger Immersion in 0°C water for 20 min. Repeated in in summer and winter	1. Time to CIVD 2. T_s at CIVD 3. ΔT_s during immersion	1. No seasonal variation was found.
LeBlanc, J., et al., 1975	1. 7 Quebec City mailmen	1. Cold Hand Test (CHT) 2. Cold Face Test (CFT) 3. Tested in Oct. and May	1. CPR 2. HR 3. T_s (cheek)	1. Decreased CPR found in May. 2. Increased bradycardia found in May. 3. T cheek was warmer ($P<.01$) in May (CFT) with no wind, and for first 7 of 16 mins. with 40 mph. wind ($P<.05$).
Davis, T.R.A., Johnston, D.R., 1961	1. 6 male Caucasians for Oct. to Feb. 2. 5 males for Feb. to Sept.	1. Whole Body Exposure to 14°C air for 1 hr., 1/min.	1. O_2 Consumption (MR) 2. Shivering 3. T skin	1. MR and shivering fell monthly from Sept. to Feb. 2. Shivering increased from Feb. to Sept.

Hand Size

In any group of subjects, one would expect a variety of weights, heights, and shapes including the size of their hands. That the size of a subject's hand may affect the cooling rate of the hand, and consequently the cardiovascular response, has received little attention. LeBlanc (1975b) suggests that a smaller body has proportionally a larger surface area. Fourier's Law of Heat Flow (as articulated by Folk, 1974) states that:

> "heat loss per minute is directly proportional to the body surface (area) . . ."

In a study of heat flow from hands immersed in ice water, Hildes et al. (1961) found an inverse relationship between hand volume and heat loss per 100 ml. of hand. Further, Little (1968) has observed a similar relationship for heat loss per 100 ml. of foot during a sixty-minute exposure of one foot to 0°C air. However, Eagan (1963) reports no influence of finger size to temperature responses of a finger immersed in ice water.

Comparison of the Cold Exposure Tests

A wide variety of tests have been developed to measure man's responses to and tolerance of cold exposure. Few researchers have undertaken to correlate the results from these various tests, yet authors consistently compare results from one cold test to another. An example of this comparison is Eagan's (1963) comparison of his results involving physical fitness, mountaineers, and finger immersion studies with Adams and Heberling's (1958) study of physical fitness and whole body cold exposures. However, LeBlanc et al. (1975) has reported a

correlation ($r=.62$, $P<.01$) between the CPR to the CHT and the CFT.

A further means to test the validity of comparing results from one cold test to another is to compare the results of the various tests as applied to one specific population. Hanna (1979), in a review of the laboratory and field studies of responses of Peruvian Indians to cold, carried out by Little (1968) and others, concluded that laboratory studies which approximate actual conditions of cold exposure will predict most accurately the results and responses of field studies. A review of the results of finger immersion studies, and CPR to the CHT, as supplied by Itoh (1974), reveals that the Ainu of Japan have a lower CPR to the CHT and maintain warmer fingers during finger immersions in ice water, than control groups. Irving et al. (1960) and Elsner et al. (1960), in studies of Kutchin Indians, have reported that the natives demonstrate earlier vasodilation and less pain to the CHT than Caucasian controls; and the natives shiver less and sleep longer during the Scholander sleeping test in cold air. The above results are indicative that the natives have adapted to cold exposure by responding less and suffer less discomfort during cold exposure.

The physical similarity of the finger immersion and CHT would suggest that results may be similar and the above review supports such a conclusion. The lack of research comparing extremity cold exposures and whole body cold exposure leads one to conclude that some research is necessary to support the many studies that make such comparisons.

Summary Statement

Many of the aspects of man's physiological responses to cold have been studied, but a number of questions still remain. However, from the

studies reviewed, a number of generalizations may be drawn. Primitive peoples have both adapted over generations and may acclimatize within a lifespan to chronic cold exposure. Occupations such as fishing, which provide a repeated exposure to cold, may necessitate an acclimatization to the stress. An extended regime of exercise would appear to improve man's tolerance to cold exposure, but fitness levels, per se, have provided only ambiguous results as a means of improved tolerance to cold. The depth of subcutaneous fat is certainly an important factor in survival and tolerance to whole body cold exposure, but, again, in extremity exposure results are minimal and ambiguous. The limited amount of research and the contradictory results in studies of age, sex, and hand size as factors which may modify vascular responses to extremity cold exposure suggest more research is necessary.

METHODS AND PROCEDURES

Sample

A total of thirty-five volunteers were tested, including twenty-two males and thirteen females. The subjects were drawn from a University of Alberta Physical Education - Outdoor Education class (14), staff from the Department of Physical Education (2), and members of a local canoe club (19). Though not a random sample, a wide range of subjects were encouraged to participate. Testing was carried out from early February to late April, 1980.

Independent Variables

1. Age

   Each subject's age was recorded as of the day of testing.

2. Body Fat

   Per cent body fat was determined by the technique of underwater weighing, as described by MacNab and Quinney. One exception was made on the advice of Dr. Quinney, that the vital capacity of each subject be measured directly after surfacing on each trial.

3. Physical Fitness

   Predicted aerobic capacity ($mlO_2/kg/min.$) was used as the measure of physical fitness. Astrand's (1970) six-minute bicycle ergometer test was used to predict the aerobic capacity. In order to reduce error, the test was repeated after a four to

ten minute rest, or when the subject felt comfortable, and the larger of the two results was used for the study.

4. Hand Volume

Hand volume was measured by displacement of water. For this, the inner of two wide-mouthed metal cans was completely filled with water. The subject immersed his hand to the styloid process of the ulna, the overflow water was caught in the larger can and transferred to a 1,000 ml. graduated cylinder for measurement. The volume of the water caught gave a measure of the volume of the hand.

Experimental Protocol

All testing was carried out with the subject at least one hour after eating. By the time the first subject in an evening's study group undertook the CHT, he or she would have been at least two hours post meal time. Two, three, and occasionally four subjects were tested at each session. All testing observed the following schedule:

1. body fatness - underwater weighing.
2. Astrand six-minute bicycle test.
3. the CHT.
4. hand volume measurement.

All testing occurred at room temperature (21°C $\pm$ 1°C).

The Cold Hand Test - Dependent Variables

The CHT commenced with a 15-minute stabilization period. During this time, heart rate and arterial pressure were determined and recorded

every 5 minutes. Heart rate (HR) was noted from a continuous read-out cardiotachometer (manufactured by Cardionics AB, Sweden). Arterial pressure was measured on the non-dominant arm with an electronic sphygmomanometer, which contained microphones in the pressure cuff to record arterial sounds (Model SD-500, manufactured by G & W Applied Sciences Laboratories). To record the cooling of the hand a 30-gauge copper-constantan thermocouple was attached to the pad of the middle finger of the dominant hand. Thus, skin temperature of this finger was recorded continuously for 2 to 3 minutes prior to immersion and throughout the immersion and recovery periods. The thermocouple output was recorded on a two-channel strip chart potentiometer (Honeywell, Model K19). The outflowing water temperature was recorded on the second channel.

The immersion phase of the CHT began after the blood pressure had stabilized. This began with the lowering of the dominant hand into the circulating water bath to the styloid process of the ulna. The water bath was held at 1°C (±2°C), and the hand remained immersed for 2 minutes. The water bath consisted of a 4.5 litre metal container into which water at the desired temperature was pumped from a large refrigerated and insulated holding tank. During the immersion phase, and for the 2-minute recovery phase of the CHT, HR was recorded at 10 seconds, 30 seconds, and then every 30 seconds; and arterial pressure was recorded every 30 seconds. Three or four minutes after removing the hand from the water, the subject was requested to rate the pain he or she had perceived during immersion on a scale of 1 to 5 (1, minimal pain - 5, unbearable pain). This response and other pertinent comments were recorded.

Statistical Analysis

Statistical analysis of the results and hypotheses involved Pearson Product Moment, and Point Biserial correlations for the five hypotheses (Ferguson, 1971). The resulting "r's" were then tested for significance on the "t" distribution and accepted at the alpha level .05 ($P<.05$ and consequently r is significantly different from 0). Hypotheses 1 to 3 were tested as 1 tail tests and hypotheses 4 and 5 as 2 tail tests. Further statistical analysis was completed, including Pearson correlations between the subjects':

1. body fatness and aerobic fitness level.
2. body fatness and hand volume.
3. body fatness and age.
4. aerobic fitness level and age.
5. increase in arterial systolic pressure and pain response during the CHT.
6. increase in arterial systolic pressure and decrease in finger temperatures.
7. first and second bicycle ergometer tests.

Significant difference of Means ("t" distribution) were undertaken, comparing the men and women with regard to aerobic fitness levels, body fatness, age, and hand volume.

Limitations of the Study

The interpretation of the results of this study is limited by a number of factors for which no control was made. Eagan (1963) suggested that the specific dynamic action of protein may alter responses to cold

exposure (LeBlanc, 1980). Even a cursory review of the ethnic studies demonstrates that genetic endowment modifies responses to cold exposure. LeBlanc and Potvin (1966) have observed that anxiety produced from mental arithmetic tests increases blood pressure. Thus, anxiety can be seen to alter sympathetic tone, which would modify response to cold exposure. Each subject's individual habits would provide different cold exposure possibilities and, consequently, individuals would each have differing levels of habituation or possibly even acclimatization to cold exposure. Lastly, the non-random selection of subjects reduces the generality of the results to the larger Canadian population.

RESULTS

The pattern of the pressor response and its magnitude is illustrated in Figure 4-1. Subject TH demonstrates a strong CPR, whereas BB shows a weaker CPR. Similarly, the drop in finger temperature when the hand is immersed in cold water is illustrated in Figure 4-2. TH shows the greater drop in finger temperature; whereas, subject RM demonstrates a smaller change in finger temperature.

FIGURE 4-1

Systolic Arterial Pressure Changes to the CHT

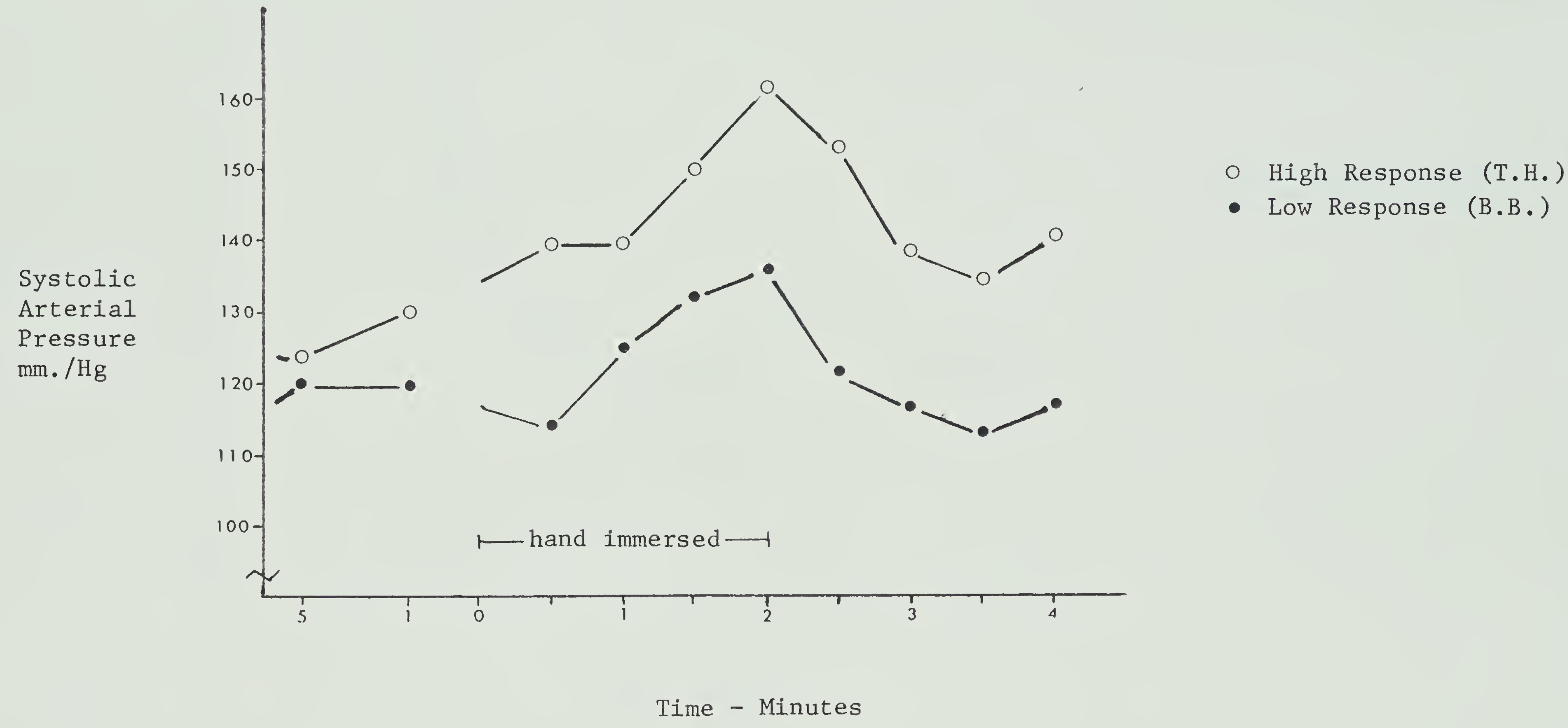
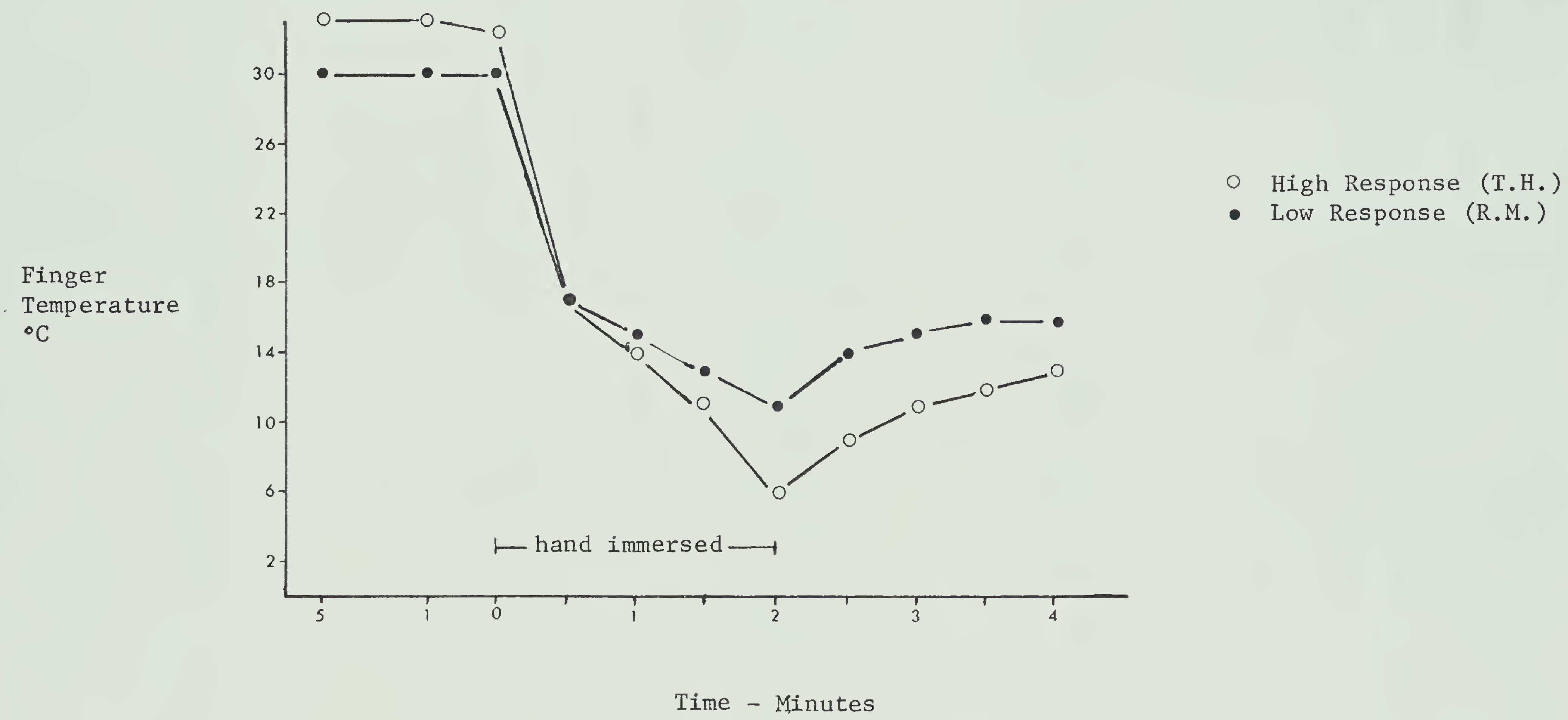


FIGURE 4-2

Finger Temperature Changes to the CHT



The analysis of the results is reported in three sections, the descriptive statistics of the sample and the interrelationships of the independent variables, the analysis of the five hypotheses, and an analysis of the dependent variables for internal validity.

Independent Variables

Age and Sex

The twenty-two male subjects ranged in age from 21 to 57, and the females from 19 to 40. There was no difference in the average ages of the two groups.

Body Fat

The proportion of body fat of the male subjects ranged from 12.3% to 26.3%, of the females from 19% to 40%, and the females were found ($P < .01$) on the average to have a larger proportion of body fat than the men. It was observed that the proportion of body fat increased with age ($r = .416$, $P < .05$). The subjects, when compared to normative data tables for Canadians, were found to be 37% overfat or were "below average," 26% of average proportion body fat, and 37% of an ideal or slim proportion of body fat (Can. Pub. Health Assoc., 1978).

Physical Fitness

The subjects exhibited a wide range of predicted aerobic capacities. The aerobic capacities for the males ranged from 31 to 81 ml/kg/min., and for the females from 31 to 59 ml/kg/min. These aerobic capacities have been compared to tables of normative values to develop physical fitness scores. The subjects, when compared to

Swedish normative tables (Astrand, 1962) scored from low to high, with 57% of the subjects above average; but, when compared to Canadian norms (Bailey), 91% of the subjects were above average fitness. A correlation was found ($r=-.639$, $P<.001$) such that the less fit subject tended to have a larger proportion of body fat. A tendency was displayed for age to negatively correlate with aerobic capacities, and the males on the average had a larger aerobic capacity than the female subjects (males = 52 ml/kg/min., females = 42 ml/kg/min., $P<.05$).

Hand Volume

The female subjects, as one would expect, had smaller hands (260 to 365 c.c.) than the males (340 to 550 c.c., $P<.001$). A tendency within the sexes for hand volume to correlate with per cent body fat was found (men $r=.381$, $P<.2$; women $r=.428$, $P<.2$).

The Hypothesis

Body Fatness

No relationship between the per cent body fat and CPR was evident during the CHT.

Physical Fitness

No relationship was observed between the predicted aerobic capacity (ml/kg/min.) and CPR during the CHT.

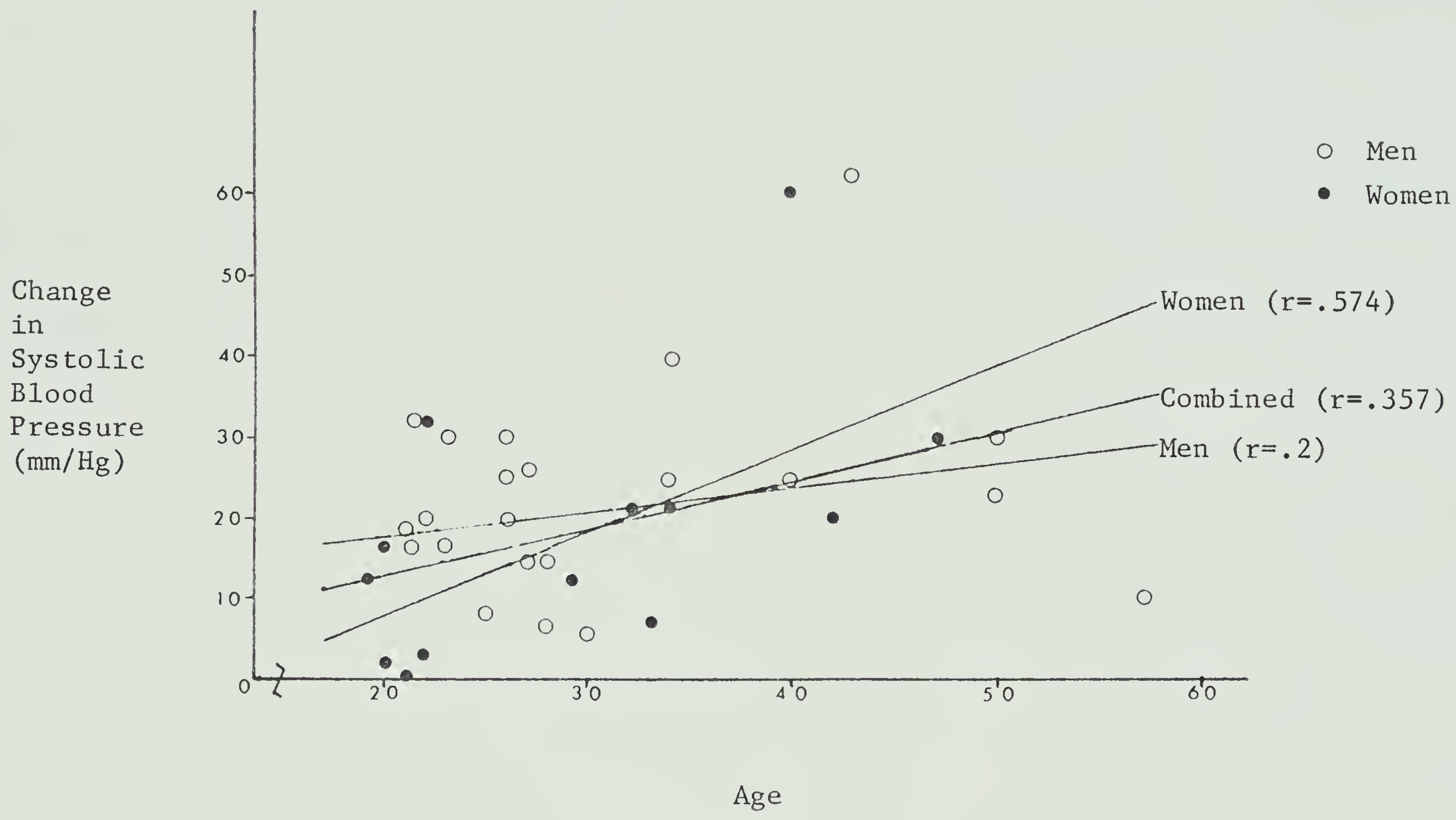
Age and the CHT

A low correlation was found: the older subjects exhibited a larger CPR during the CHT ($r=.357$, $P<.05$, see Fig. 4-1). This

relationship was even more pronounced with the female subjects ($r=.574$, $P<.05$).

FIGURE 4-3

Relationships Between Age and Change in Systolic Blood Pressure During the CHT

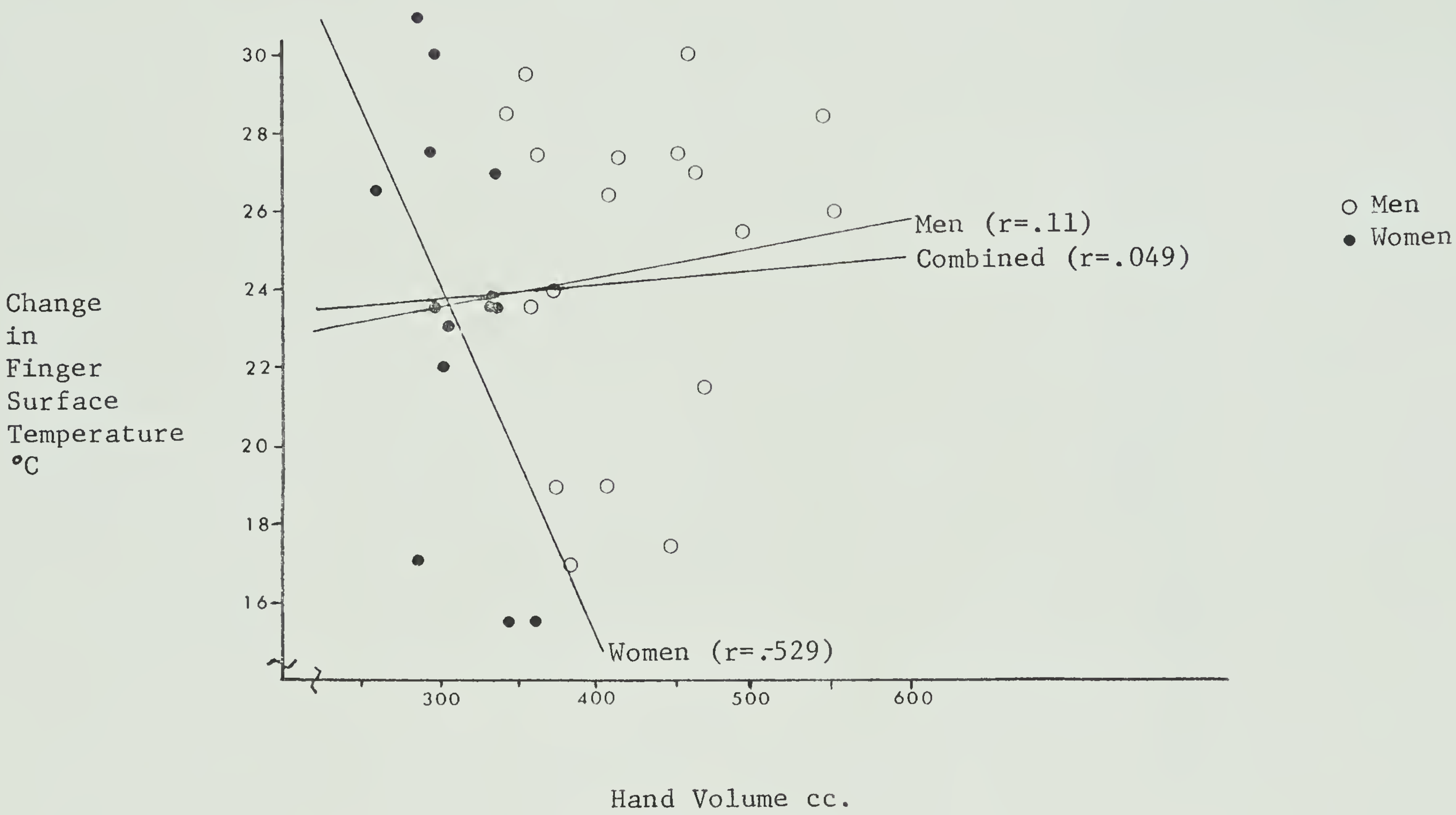


Hand Size

The hand size of the subjects was found to bear no relationship to their CPR or decrease in finger temperature during the CHT. The female subjects, though, did display a strong tendency for those with larger hands to relate to a smaller decrease in finger temperature ($r=-.529$, $P<.1$).

FIGURE 4-4

Relationships Between Hand Volume and
Finger Temperature Changes During the CHT



Sex

No difference between male and female subjects was observed in the CPR to the CHT.

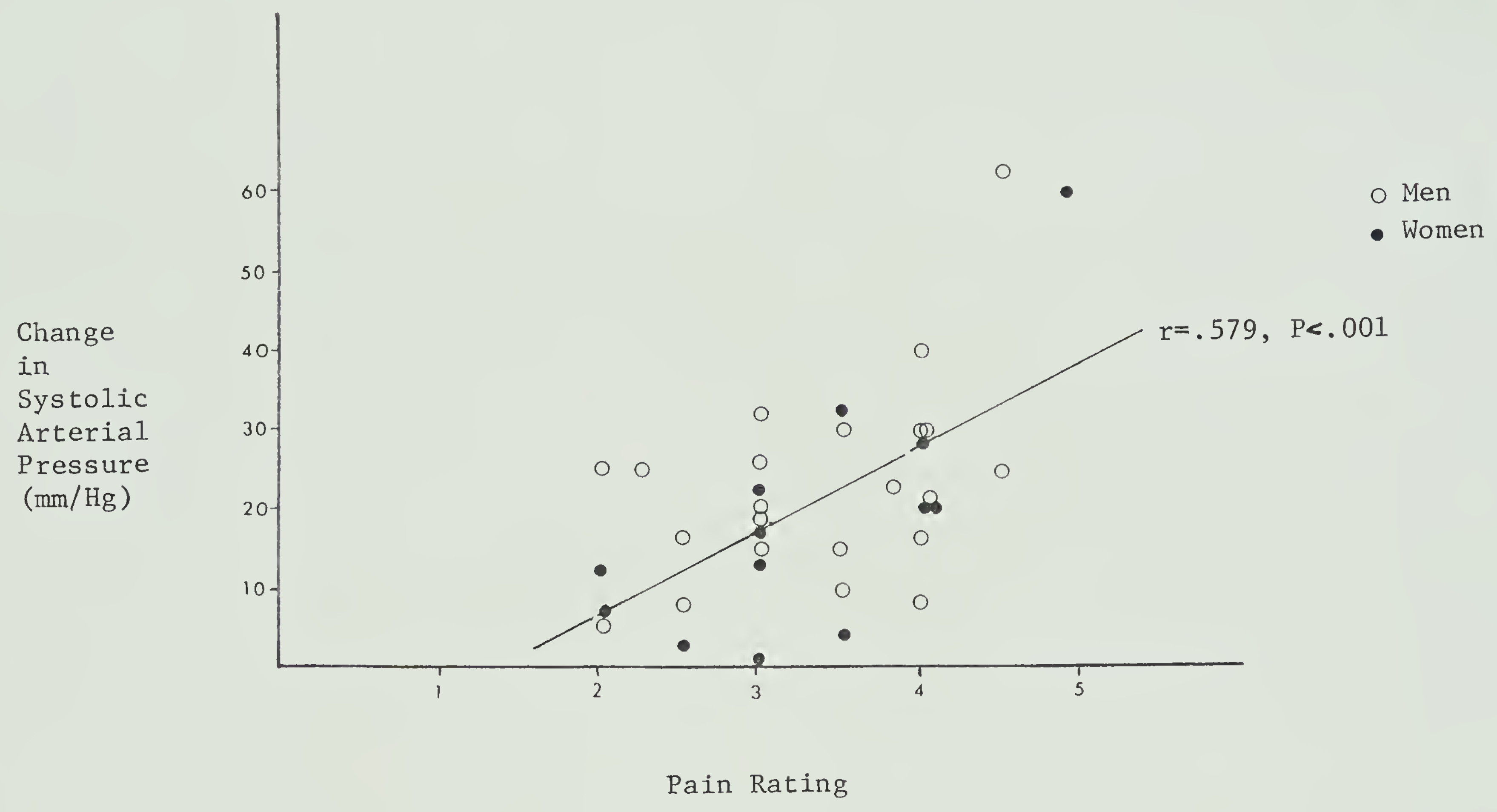
Internal Validity

Pain and the CPR

The subjects' rating of perceived pain during the CHT correlated with their CPR ($r=.579$, $P<.001$).

FIGURE 4-5

Relationships Between Change in Systolic Arterial Pressure Changes and Subjects' Ratings of Perceived Pain During the CHT

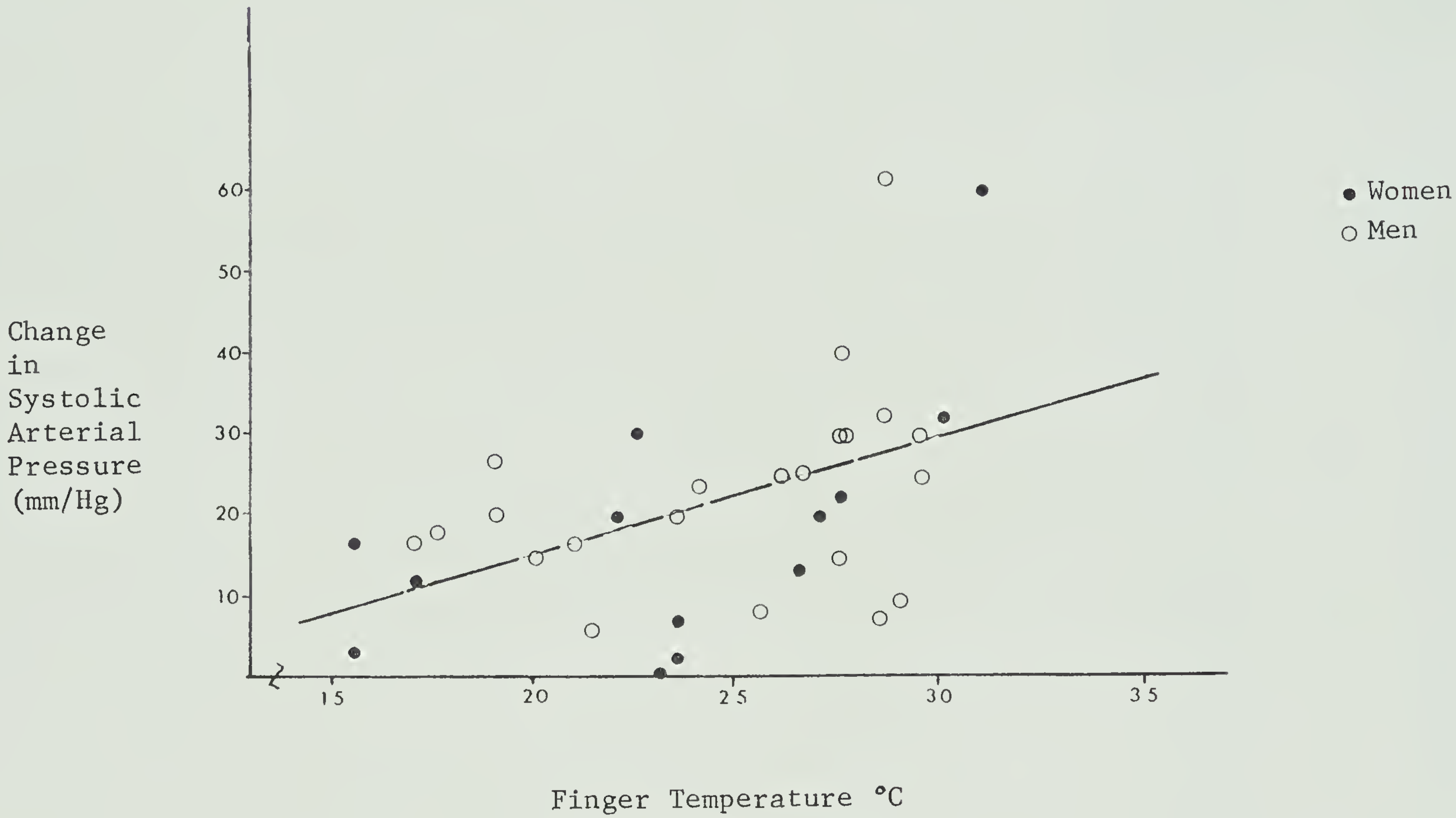


The CPR and Finger Temperature Changes

The CPR and the reduction in blood flow to the finger surface, as evidenced by the reduced finger temperature, during the CHT are both cardiovascular responses to the cold. A strong CPR correlated with a large fall (change) in finger temperature during the CHT ($r=.485$, $P<.01$).

FIGURE 4-6

Relationships Between Systolic Arterial Pressure Changes and Changes in Finger Temperature During the CHT



Pilot Test versus the Thesis Testing

Six subjects were common to both a pilot study and the present study. A "T" test was applied to the mean systolic blood pressure changes between these two studies, and showed no difference between the means of the two studies.

Fitness Test

A high correlation was found between the two Astrand bicycle ergometer tests ($r=.799$, $P<.001$).

DISCUSSION

The findings of this study do not support the hypothesis that improved tolerance to cold, as reflected by a low cold pressor response (CPR) to the cold hand test (CHT), may be the result of high levels of physical fitness, a high proportion of body fat, large hands or sex. This suggests, further, that the reduced CPR seen in Eskimos (LeBlanc et al., 1975) and fishermen (LeBlanc et al., 1960) is not just a reflection of these peoples being more physically fit.

It is possible that the failure of this study to find a negative correlation between levels of physical fitness and magnitude of CPR is a reflection of an insufficiently wide range of levels of physical fitness among the subjects tested, particularly lower levels of fitness. Unfortunately, the majority of the volunteers for this study were above average to highly physically fit. Their volunteering for this study likely reflects their personal interest in fitness, and the inducement of the free fitness evaluation offered by the study. The low numbers of poorly fit subjects tested may have limited the power of the statistical procedures used to delineate any difference in CPR between the physically fit and unfit subjects.

Several of the authors reviewed (Adams and Heberling, 1958; Andersen et al., 1966) reported that improved levels of physical fitness reduce metabolic response to whole body cold exposure, and LeBlanc et al. (1978) observed a correlation between high levels of physical fitness and a reduced CPR to the CHT. This study, in many respects, was modelled on the previous works by LeBlanc, yet the results relating fitness and CPR

differ. LeBlanc et al. (1978) used a direct measure of aerobic capacity on the bicycle ergometer in contrast to the predictive test used by this study. Glassford et al. (1965) has reviewed the relationship between direct and predictive tests of aerobic capacity, and found strong correlations between the two. Predictive bicycle tests, though, tend to yield higher mean values than direct bicycle tests and underestimate MVO_2 for highly-trained athletes. LeBlanc et al. (1978) does report a lower distribution of aerobic capacities amongst his male subjects than found in the present study.

A major difference between this present study and the work of LeBlanc et al. (1975, 1978) is their use of 5°C water in contrast to the 1°C water used. The colder water in the present study was chosen for technical reasons. One may postulate that the colder water would provide a stronger stimulus and would eliminate any difference in responses which may be attributed to differing physical fitness levels, percentage of body fat, size of hand, or sex. Only contradictory evidence for such a postulation exists in the literature. Itoh (1974) reports that for finger immersion studies 0°C water (versus 5°C water) is necessary to elicit ethnic variations in vascular responses. LeBlanc (1975[b]), though, has found that hyper, moderate, and hypo reactors to the CHT maintain consistent but larger responses between water baths of 5°C and 0°C.

The evidence in the literature supports the conclusion that overall subcutaneous fat is an important insulator against whole body cold exposure, maintaining core temperature and minimizing metabolic responses to the cold (Keatinge, 1969; Buskirk et al., 1963; and Kollias et al., 1972). In addition, Little (1968) has reported that the

insulation provided by subcutaneous fat in the feet contributes to the reduction in vascular responses to extremity cooling and thus allows for warmer skin temperatures. Unfortunately, in the present study no skinfold measurements were taken. Thus, from the results found, it is only possible to conclude that the proportion of body fat of a subject has no effect on their CPR to the CHT.

This author earlier hypothesized that hand size may affect the cooling rate of one's hand; that is, larger hands may reduce the cooling rate of the hand, consequently reducing the vascular response to a cold exposure and thus improve a person's ability to tolerate cold hands. The results of this study are inconclusive with regard to this possible relationship that people with larger hands may exhibit a reduced CPR to the CHT. The women of this study, though, display a strong tendency for those with larger hands to exhibit a smaller change in finger temperature during the CHT. This tendency supports the prior work of Hildes et al. (1961) and Little (1968). This support is complicated by the observation that both the males and females of this present study display a tendency for those with a high proportion of body fat to have larger hands (males r=.381, females r=.428; $P<.2$). Thus, it may not be hand size alone which modifies the cooling rate and subsequent vascular responses to a cold exposure.

On all variables except age, the women were found to differ from the men; the women as a group were less fit, carried proportionally more fat, and had smaller hands. Yet, this study supports the results of Krog et al. (1969), Itoh (1974), and LeBlanc et al. (1978) that sex has no effect on one's vascular responses to extremity cooling.

Studies, such as Durnin and Womersby's (1974) collection of

anthropometric, skinfold measurements, and body density weighings of 481 British residents, recognize that the proportion of fat stored subcutaneously decreases with age. This relationship, and the findings of Little (1968), that subcutaneous fat reduces vascular responses to cold exposure, may contribute to the results of this study, wherein a greater CPR was found to correlate with older subjects. The previous work of Collins et al. (1980) had led to an expectation that the older subjects would exhibit a reduced cardiovascular response to cold. Both Collins et al. (1980) and Horvath et al. (1956), though, studied a wider age range of subjects than this study.

The results of this study proved to be replicable from pilot study to the present study. On the basis of our yet incomplete understanding of the mechanisms controlling cardiovascular responses, the results of this study appear to agree within themselves. That is, a correlation exists between the CPR and the magnitude of change in the finger temperature; and the CPR correlates with the pain ratings reported by each subject. The CPR found in this study is similar to that reported by LeBlanc et al. (1975, 1978).

The results of this study also support the studies reviewed above that suggest the vasoconstrictor tone maintained in the arteries and arterioles are controlled through sympathetic nerves. LeBlanc et al. (1979) has recently demonstrated with the CHT that the CPR is clearly related to levels of norepinephrine in the blood plasma, which in themselves reflect the activity level of the adrenergic fibres of the sympathetic nervous system. Thus, it appears that the cooling of the hand results in stimulation of the adrenergic fibres, and this stimulation results in:

1. increased vasoconstriction of the arteries and arterioles of the hand,
2. a lowering of blood flow to the hand and fingers,
3. a reduction in skin temperature, and
4. an increase in resistance to blood flow and in increase in arterial pressure.

The process by which subcutaneous fat and age alter the vascular responses to cold are still not clearly understood. Subcutaneous fat may reduce the rate of cooling, or may reduce the actual temperature change at the sensory nerve level and thus lead to reduction of sympathetic activity. Age appears to have its primary effect on the depth of subcutaneous fat, thus indirectly modifying the CPR. A second effect of age may be that adrenergic fibres may fail in the elderly, a postulate of Collins et al. (1980).

The mechanism by which physical fitness may modify cardiovascular responses to cold exposure is postulated to involve a cross-adaptive reduction in activity or habituation of the sympathetic nervous system. In part, this reduction in activity may be a result of norepinephrine being a common transmitter substance in the sympathetic nervous system to both cold and exercise stress.

Future studies dealing with extremity exposure to cold and cardiovascular responses may well consider the following:

1. Due to the strong evidence suggesting that subcutaneous fat is an important insulator during cold exposure, direct skinfold measurements of the extremity tested should be made. Ancillary to this, there is a need to relate skinfold measurements of the hand to other skinfold

measurements of the body and to percentage of body fat as calculated from underwater weighings.

2. Ice water or water at 0°C may be an overly intense cold exposure; consequently, future studies should use water baths with a temperature range of 5-10°C. Such a temperature range may more readily discriminate the effects of the various factors which may modify cardiovascular responses to cooling. Further research is needed to complete our understanding of the range of cardiovascular responses to extremity cooling in cold water between the temperatures of 0 and 10°C.

SUMMARY

The possible relationship between the magnitude of the cold pressor response (CPR) and physical fitness, and four other parameters has been investigated. The CPR was elicited by immersion of the dominant hand in stirred 1°C water (CHT) and evaluated on the basis of changes in arterial systolic blood pressure. Previous authors have reported the CPR to be less in subjects who were considered acclimatized to cold hand exposure (Eskimos and fishermen). Other workers have also found that improved physical fitness reduces other similar physiological responses to cold exposure. This possible relationship between magnitude of CPR and physical fitness, per cent of body fat, hand volume, age, and sex was evaluated in a group of thirty-five male and female subjects.

The five independent variables were measured. Physical fitness was evaluated using a predictive bicycle ergrometer. Body fatness was computed from underwater weighings. Hand volume was measured by water displacement. Age and sex were recorded on the test day.

Coefficients of correlation were calculated between the five parameters and the subjects' CPR. The results indicate no relationship between per cent body fat, physical fitness, age, sex, and the subjects' CPR. A correlation was displayed such that older subjects showed a greater CPR. The author suggests this may reflect the reduced subcutaneous fat associated with aging. Although no correlation was found between hand size and the CPR, the female subjects did exhibit a strong tendency for larger hands to maintain a warmer finger during the CHT.

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APPENDIX 1

Appendix 1-A. Whole Body Cold Exposure Test Procedures

Appendix 1-B. Scholander Sleeping Test Procedures

Appendix 1-C. Finger Immersion Test Procedures

APPENDIX 1-A

Whole Body Cold Exposure Test Procedures

The whole body cold exposure test uses the increased metabolic rate (metabolic response-MR) as one of the criteria of tolerance to cold. Other criteria used in the test include magnitude of change of the rectal temperature, mean skin temperature and change of skin temperature of the extremities, especially the arms and hands.

The procedures for a whole body cold exposure reported below are those used by Adams and Heberling (1958, 1961). Their procedures were as follows:

i. Each subject reported to the laboratory first thing in the morning in a fasting state.

ii. To overcome fasting alone as a stress, each subject ate a small standard amount of food 30 minutes prior to entering the cold room.

iii. Prior to entering the cold room, thermocouples and other accessory equipment were attached to the semi-nude subjects.

iv. The subjects dressed only in cotton shorts were carried into the cold room, covered by two woollen blankets on a plastic wire mesh litter.

v. After entering the cold room (10° C) the subjects remained covered and additional equipment was attached, and 10 minutes of control observations were made.

vi. After the control observations, the blankets were removed and the subjects remained supine for the

one-hour exposure.

vii. Measurements made included skin temperature (as per Hardy and DuBois, 1938), rectal temperature, and oxygen consumption was measured continuously using an open circuit indirect calorimetric technique, as proposed by Weir (1949).

viii. Calculations from the above data included average skin temperature (Hardy and DuBois, 1938) and average body temperature (Burton, 1935).

A wide range of variations on the above procedures have been used. The primary two variations have been the length of the cold exposure, and the air temperature of the cold exposure. The length of the exposure has ranged from as short as 10 minutes with elderly subjects to as long as 6 1/2 hours with British sailors. A majority of the tests have used a 1 to 2 hour length of exposure. The air temperature during exposure has ranged from 5°C to 14°C, and the majority have used 10°C air for the cold exposure.

The Fox Bed Test is a variation on the whole body cold exposure and uses an air-conditioned bed. Rather than testing at one temperature, a cycle of air temperatures is used, and the capacity of the body to respond and thermoregulate is stressed.

APPENDIX 1-B

Scholander Sleeping Test

This cold exposure test uses the ability to sleep under cold conditions as the criterion of tolerance to cold. The method reported below is that as originally developed by Scholander et al. (1958). The test required a room which could be maintained at both 20°C and 3°C, and a test was conducted at each temperature. Testing occurred from 11:00 p.m. to 7:00 a.m. For the 20°C exposure the subjects slept nude except for shorts, and they slept on a mesh cot. The 3°C exposure involved the semi-nude subjects sleeping on the cot, in a light woollen bag which had a clo[1] value of 2. The measurements taken included:

i. Rectal temperature and skin temperatures from the scapular region of the shoulder, the lateral portion of a thigh and the dorsal surface of the foot.

ii. Heat production (MR) was estimated from oxygen consumption. The subjects slept with their heads in a ventilated hood. Thirty to fifty litres of air per minute were drawn through the hood. A seven-minute sample was drawn each half-hour during the night.

iii. Shivering and sleep were observed visually and by means of an electromyograph, using metal discs pasted to the skin.

Scholander et al. (1958) found that men acclimatized to cold were able during the 3°C test to maintain warmer skin temperatures, exhibited a

1. 1 clo equals the insulation required to maintain constant body temperature at 21 C (approximately equals a light business suit).

greater MR, and were able to sleep much more than a control group. Andersen et al. (1966), with a similarly acclimatized group of subjects, found similar results.

APPENDIX 1-C

Finger Immersion Cold Test Procedures

The measurement of temperature changes of the skin of one finger immersed into stirred ice water was popularized as a cold exposure test by Lewis (1930). Various parameters have been used to indicate tolerance to the procedures. It has been reported that individuals acclimatized to cold do not exhibit in the exposed finger as large a decrease in finger temperature, nor does the finger drop to as low a temperature, as controls. The time to CIVD and magnitude of CIVD the mean skin temperature have all been reported as parameters of cold tolerance.

Eagan (1963) developed the following procedures:

i. Subjects slept overnight in the laboratory in a comfortable environment.

ii. No food was allowed after 6:00 p.m.

iii. All testing occurred between 6:00 a.m. and 10:00 a.m.

iv. Subjects were not allowed to leave their bed within 1 hour of testing.

v. BMR and finger immersion tests were conducted with the subjects in bed.

vi. The finger immersion consisted of immersing the distal 2.8 cm. of the index finger into stirred ice water for 10 minutes.

vii. The skin temperature was measured continuously on the volar pad, and pain was estimated each minute.

The major variations on Eagan's procedures have been to drop the

extensive control period prior to the test, and to use a finger immersion of twenty minutes (Itoh, 1974).

APPENDIX 2

APPENDIX 2-A

RESULTS TABLE

RESULTS TABLE

Subject	Age	Sex	% Fat	MVO_2	Weight	Hand Vol.	Min. T_f (°C)	ΔT_f (°C)	ΔBP_{sy} (mm/Hg)	ΔBP_{dia} (mm/Hg)	H.R. (b/min.)	Pain
K.B.	19	F	31.6	47.5	144	280	7	17	12	4	12	2
J.E.	20	F	29.8	41	146	365	6.5	15.5	16	16	18	3
R.H.	22	M	13.5	57.5	153.25	360	11.5	23.5	20	26	8	3
C.R.	32	F	26.5	44	135	300	11	22	20	12	1(12)	4
G.M.	27	M	12.5	51	157	405	8	19	26	26	12	3
S.M.	23	M	13.8	51	149	-	6	21	16	16	-6	2.5
T.H.	21	M	23.1	48	165	-	6	28.5	32	10	6	-
B.B.	21	M	21.2	31	183	380	6.5	17	16	18	4	4
E.M.	25	M	19	44	177	490	11.5	25.5	8	9	-10	2.5
B.S.	27	M	21.7	41	183.5	-	11.5	20	15	16	2(6)	3.5
W.W.	21	M	16	64	191	445	11	17.5	17	10	6(8)	3
R.M.	26	M	13.8	59	160.25	370	11	19	20	16	0(8)	4
L.D.	22	F	27.1	47	136	340	9.5	15.5	3	22	-10(12)	3.5
D.M.	21	F	20.47	41	141	310	12	23	0	7	13	3

RESULTS TABLE

Subject	Age	Sex	% Fat	MVO_2	Weight	Hand Vol.	Min. T_f (°C)	ΔT_f (°C)	ΔBP_{sy} (mm/Hg)	ΔBP_{dia} (mm/Hg)	ΔH.R. (b/min.)	Pain
P.W.	50	M	26.6	48	146	370	9	24	23	23	-	3.8
A.S.	34	M	20.9	58	201	550	7.5	26	25	18	6	2.5
M.S.	33	F	25.38	31	156	330	3.5	23.5	7	15	31	2
J.K.	34	M	20	47	190	415	5	27.5	40	34	48	4
M.A.	26	M	9.6	67	145	355	6	29.5	30	20	-	4-
B.P.	40	F	20	42	100	280	4.5	31	60	40	12	4.9
W.C.	57	M	26.3	40	155	410	6.5	29	10	16	12	3.4
H.S.	40	M	25.2	51	220		6	29.5	25	14	16	2

RESULTS TABLE

Subject	Age	Sex	% Fat	MVO_2	Weight	Hand Vol.	Min. T_f (°C)	ΔT_f (°C)	ΔBP_{sy} (mm/Hg)	ΔBP_{dia} (mm/Hg)	H.R. (b/min.)	Pain
G.G.	28	M	16.7	62	162	340	6	28.5	7	11	6	4
G.C.	50	M	25.7	60	160	450	8.5	27.5	30	12	6	3.5
S.W.	26	M	12.3	81	150	410	7.5	26.5	25	18	6	4.5
B.W.	23	M	21.25	56	153	360	8.5	27.5	30	30	-	4-
R.R.	28	M	16.6	55	191.6	460	8.5	27	15	16	-(12)	3
E.H.	29	F	26.4	32	100.3	260	5	26.5	13	18	6	3
M.H.	30	M	21.8	38	202	470	14	21.5	6	12	4	2
C.W.	22	F	17.6	48	123.5	295	7.5	30	32	28	22	3.5
B.R.	20	F	18.4	59	128	290	10	23.5	2	-	-	2.5
E.M.	42	F	35.8	38	168.5	330	5.5	27	20	20	8	4
J.P.	47	F	28.8	28	137	330	4	23.5	30	14	8	4
C.K.	34	F	18.9	59	124	290	5.5	27.5	22	22	3	3
A.P.	43	M	26.3	39	187	540	7	28.5	62	30	18	4.5

APPENDIX 2-B

General Information

NAME ______________________________

ADDRESS ___________________________

CITY ______________________________ PROVINCE ________________________

WAIVER

I, _______________________ hereby agree to undertake an exercise fitness and cold response test designed to determine my physical work capacity, responses to cold and body density. I understand that I will perform tests of work capacity on a bicycle ergometer, the submersion of one hand in cold water and/or a 2 hr. rest in a cool room, and a dunking weigh-in, in a body density tank. During these tests my heart rate, blood pressure, various skin temperatures, oral and/or rectal temperatures may be monitored and measured.

I understand that with any type of exercise/cold test there are potential risks and at any time during the test I experience unusual discomfort I will ask to discontinue the test.

In agreeing to such an examination, I waive any legal recourse against the University of Alberta from any and all claims resulting from this fitness test.

Date: ______________________ Subject: ______________________________
(signature)

Witness: ____________________________

APPENDIX 2-C

Personal Data

AGE ________ SEX ________ WEIGHT ____________

HEIGHT ____________

RECENT ILLNESS ____

PRESENT OR RECENT DRUGS ____

GENERAL ACTIVITY LEVEL TYPE OF WORK ____________________________

FAVORITE RECREATION ___________________________

	YES(✓)
Has your doctor ever said you have heart trouble?	☐
Do you frequently suffer from pains in your heart or chest?	☐
Do you often feel faint or have spells of service dizziness?	☐
Has a doctor ever said your blood pressure was too high?	☐
Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise or might be made worse with exercise?	☐
Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?	☐
Are you over age 69 and not accustomed to vigorous exercise?	☐

APPENDIX 2-D

Hand Pressor Test

DATE ________________ TIME ___________ LOCATION _________________

EQUIPMENT: RECORDER ___________________

WATCH ______________________

WATER TEMP. IN BATH ___________________

SPHYGMOMANOMETER ______________________

CARDIOTACH ___________________________

DATA:

SUBJECT ______________________________

TIME	B.P.	H.R.
-15		
-10		
-5		
-1		
30		
1:00		
1:30		
2:00		
2:30		
3:00		
3:30		
4:00		

Related Data:

(1) Be sure to attach thermocouples to middle finger and to water outlet. Attach trace to this page.

(2) Request a rating of pain. 1 (minimal pain, would have been able to leave hand in the water indefinitely) -- 5 (unbearable pain, would have been unable to complete the 2-minute immersion)

____

APPENDIX 2-E

Body Density

(1) MEASUREMENTS

(a) Wt. in air ____________lbs.

(b) Vital Capacity (L) x 61.02 ____________cu.in.

(c) Residual Volume - 25% male or 30% female of V.C. ________cu.in.

(d) Vol. Gastro-intestinal tract 7.01 cu.in.

(e) Wt. in water (with full inspiration) ____________lbs. -

Weight belt ____________lbs. = ____________lbs. (negative)

(2) CALCULATIONS

(f) Total body air; V.C. + R.V. + V.G.I. = _____________cu.in. x

.0362 = ____________lbs.

(g) True weight in water = Weight in water (from e above)

____________lbs. plus total body air (from f) ____________lbs.

= ____________lbs.

(h) Body volume - Wt. in air (from a) ____________lbs.

minus true weight in water (from g) ____________lbs. =

____________lbs.

(i) Body density = $\frac{\text{Wt. in air}}{\text{Body vol.}}$ $\frac{\text{(a) \_\_\_\_\_\_\_\_\_\_\_\_}}{\text{(h) \_\_\_\_\_\_\_\_\_\_\_\_}}$ x

____________density of water = ____________

(j) $\frac{\text{\% Fat} = 4.570 - 4.154}{\text{Body Density (i) \_\_\_\_\_\_\_}}$ x 100 = ______________%

APPENDIX 2-F

Astrand Bicycle Ergometer Test

DATE ________________ TIME ___________ LOCATION ______________________

EQUIPMENT: CARDIOTACH ____________________

WATCH _________________________

METRONOMES ____________________

DATA:

SUBJECTS

NAME: 1.____________ 2.____________ 3.____________ 4.____________

BICYCLE
PRETEST H.R.

H.R. Min. 5

H.R. Min. 6

H.R. Additional

H.R. Additional

Work Load

Power Output

AGE CORRECTION FACTOR
l/min.
MVO_2 ml/kg. x min.

NORMATIVE RATING

APPENDIX 3

APPENDIX 3-A

Norms by Age-Group for Percentage Body Fat

	MALES				
Age (Yrs)	20-29	30-39	40-49	50-59	60-56
Slim	12	14	14	15	15
Ideal	13-17	15-18	15-19	16-20	16-20
Average	18-22	19-23	20-24	21-25	21-26
Below Average	23-27	24-28	25-29	26-30	27-31
Overfat	28	29	30	31	32

	FEMALES				
Age (Yrs)	20-29	30-39	40-49	50-59	60-65
Slim	13	13	14	15	15
Ideal	14-18	14-19	15-20	16-21	16-21
Average	19-23	20-24	21-25	22-26	22-26
Below Average	24-28	25-29	26-30	27-32	27-32
Overfat	29	30	31	33	33

(from Can. Pub. Health Assoc., 1978)

APPENDIX 3-B

Distribution of
Norms for Male Subjects Tested in the Saskatoon Sample

AGE	FITNESS RATING STEP TEST	N	MEAN BICYCLE VO_2 MAX. (ml/kg/min.) $\pm$ 1 S.D.
15-19		90	44.2 $\pm$ 8.0
	Low	6	36.0 $\pm$ 5.0
	Below Average	41	42.3 $\pm$ 8.3
	Average	24	44.5 $\pm$ 4.4
	Above Average	11	46.7 $\pm$ 5.2
	High	8	55.1 $\pm$ 3.9
20-29		88	36.9 $\pm$ 8.2
	Low	10	28.7 $\pm$ 6.7
	Below Average	47	34.8 $\pm$ 6.1
	Average	9	40.1 $\pm$ 8.9
	Above Average	13	41.2 $\pm$ 5.5
	High	9	48.1 $\pm$ 6.6
30-39		148	32.9 $\pm$ 6.4
	Low	8	23.3 $\pm$ 2.7
	Below Average	66	30.2 $\pm$ 4.7
	Average	21	35.0 $\pm$ 5.0
	Above Average	22	34.0 $\pm$ 5.3
	High	31	38.8 $\pm$ 5.8
40-49		76	27.2 $\pm$ 5.8
	Low	2	17.0 $\pm$ 1.4
	Below Average	21	24.1 $\pm$ 4.6
	Average	22	25.5 $\pm$ 3.9
	Above Average	6	29.1 $\pm$ 3.0
	High	25	31.5 $\pm$ 5.8
50-59		63	25.7 $\pm$ 4.9
	Low	--	---- ---
	Below Average	12	20.4 $\pm$ 3.9
	Average	14	24.9 $\pm$ 3.6
	Above Average	19	26.6 $\pm$ 3.8
	High	18	28.7 $\pm$ 4.7
60-69		31	22.6 $\pm$ 4.8
	Low	1	12.0 $\pm$ ---
	Below Average	5	19.0 $\pm$ 1.7
	Average	2	21.9 $\pm$ 2.8
	Above Average	13	21.9 $\pm$ 2.8
	High	10	26.9 $\pm$ 4.7
Entire Male Sample		496	33.2 $\pm$ 9.4

(from Bailey)

APPENDIX 3-C

Norms for Female Subjects Tested in the Saskatoon Sample

AGE	FITNESS RATING STEP TEST	N	MEAN ASTRAND VO_2 MAX. (ml/kg/min.) $\pm$ 1 S.D.
15-19		122	34.3 $\pm$ 9.2
	Low	40	26.8 $\pm$ 7.9
	Below Average	44	34.0 $\pm$ 6.2
	Average	21	41.8 $\pm$ 6.6
	Above Average	14	42.9 $\pm$ 4.9
	High	3	46.7 $\pm$ 4.9
20-29		118	31.3 $\pm$ 6.9
	Low	41	27.3 $\pm$ 5.5
	Below Average	23	31.4 $\pm$ 6.4
	Average	34	32.6 $\pm$ 6.2
	Above Average	13	36.5 $\pm$ 6.5
	High	7	37.6 $\pm$ 7.9
30-39		134	28.4 $\pm$ 6.7
	Low	20	23.8 $\pm$ 7.7
	Below Average	42	26.2 $\pm$ 4.3
	Average	36	29.1 $\pm$ 6.5
	Above Average	22	31.6 $\pm$ 5.1
	High	14	35.0 $\pm$ 6.5
40-49		86	24.8 $\pm$ 5.7
	Low	9	17.7 $\pm$ 3.5
	Below Average	29	22.2 $\pm$ 3.8
	Average	28	26.1 $\pm$ 4.1
	Above Average	5	27.6 $\pm$ 2.0
	High	15	30.9 $\pm$ 5.7
50-59		82	22.2 $\pm$ 5.5
	Low	4	16.0 $\pm$ 4.2
	Below Average	20	18.8 $\pm$ 3.7
	Average	22	20.3 $\pm$ 3.6
	Above Average	24	25.3 $\pm$ 3.9
	High	12	27.3 $\pm$ 7.2
60-69		53	19.0 $\pm$ 4.1
	Low	4	14.0 $\pm$ 3.4
	Below Average	9	18.3 $\pm$ 1.5
	Average	13	19.2 $\pm$ 3.4
	Above Average	18	18.1 $\pm$ 4.1
	High	9	23.4 $\pm$ 13.5
Entire Female Sample		595	28.0 $\pm$ 8.4

(from Bailey)